TP 13666E

Contaminated Aircraft Simulated Takeoff Tests for the 1999-2000 Winter: Preparation and Procedures

Prepared for

Transportation Development Centre
On behalf of
Civil Aviation

Safety and Security
Transport Canada

APS AVIATION INC.

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by

Peter Dawson

APS AVIATION INC.

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Un sommaire français se trouve avant la table des matières.

PREFACE

At the request of the Transportation Development Centre of Transport Canada, APS Aviation Inc. (APS) has undertaken a multi-year research program to advance aircraft ground de/anti-icing technology. The specific objectives of the APS test program are the following:

- To develop holdover time data for Type IV fluids using lowest-qualifying viscosity samples, and to develop holdover time data for all newly qualified de/anti-icing fluids;
- To conduct flat plate holdover time tests under conditions of frost;
- To further evaluate the flow of contaminated fluid from the wing of a Falcon 20D aircraft during simulated takeoff runs;
- To determine the patterns of frost formation and of fluid failure initiation and progression on the wings of commercial aircraft;
- To evaluate whether the proposed locations of Allied Signal's wing-mounted ice sensors on an Air Canada CL65 are optimally positioned;
- To evaluate the second generation of the NCAR snowmaking system;
- To evaluate the capabilities of ice detection camera systems;
- To examine the feasibility of and procedures for performing wing inspections with a remote ice detection camera system at the entrance to the departure runway (end-of-runway);
- To reassemble and prepare the JetStar aircraft wing for mounting, to modify it to obtain cold-soak capabilities, and to conduct fluid failure tests in natural precipitation using the wing;
- To extend hot water deicing tests to aircraft in natural outdoor precipitation conditions, and to correlate outdoor data with 1998-99 laboratory results;
- To examine safety issues and concerns of forced air deicing systems; and
- To evaluate snow weather data from previous winters to establish a range of snow precipitation suitable for the evaluation of holdover time limits.

The research activities of the program conducted on behalf of Transport Canada during the 1999-2000 winter season are documented in nine reports. The titles of these reports are as follows:

- TP 13659E Aircraft Ground De/Anti-icing Fluid Holdover Time Field and Endurance Time Testing Program for the 1999-2000 Winter;
- TP 13660E Aircraft Full-Scale Test Program for the 1999-2000 Winter;
- TP 13661E A Second-Generation Snowmaking System: Prototype Testing;

- TP 13662E Ice Detection Sensor Capabilities for End-of-Runway Wing Checks: Phase 2 Evaluation:
- TP 13663E Hot Water Deicing of Aircraft: Phase 2;
- TP 13664E Safety Issues and Concerns of Forced Air Deicing Systems;
- TP 13665E Snow Weather Data Evaluation (1995-2000);
- TP 13666E Contaminated Aircraft Simulated Takeoff Tests for the 1999-2000 Winter: Preparation and Procedures; and
- TP 13667E Preparation of JetStar Wing for Use in Deicing Research.

This report, TP 13666E has the following objective:

- To further evaluate the flow of contaminated fluid from the wing of a Falcon 20D aircraft during simulated takeoff runs.

This report documents the preparation activities and the procedures developed for the trials. Because suitable weather conditions did not occur during the window when the test aircraft and crew were available, the tests were not conducted.

ACKNOWLEDGEMENTS

This research has been funded by the Civil Aviation Group, Transport Canada, with support from the US Federal Aviation Administration. This program could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Transportation Development Centre of Transport Canada, the Federal Aviation Administration, the National Research Council Canada, Atmospheric Environment Services Canada, and several fluid manufacturers. Special thanks are extended to US Airways Inc., Air Canada, National Centre for Atmospheric Research, AéroMag 2000, Aéroports de Montreal, G. Vestergaard A/S, Hudson General Aviation Services Inc., Union Carbide, Cryotech, BFGoodrich, Cox and Company Inc., Fortier Transfert Ltée, and MTN Snow Equipment Inc. for provision of personnel and facilities and for their co-operation with the test program. The author gratefully acknowledges the contribution of the APS Aviation test preparation team: Nicolas Blais, Mike Chaput, Medhat Hanna, Jeff Mayhew, and Elio Ruggi.Special thanks are extended to Frank Eyre and Barry Myers of the Transportation Development Centre for their participation, contribution, and guidance in the preparation of this document. APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data.

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Research reports produced on behalf of Transport Canada for testing during previous winters are available from the Transportation Development Centre (TDC). Nine reports (including this one) were produced as part of this winter's research program. Their subject matter is outlined in the preface.

16. Abstract

The objective of this study was to establish conditions for which contamination due to anti-icing fluid failure in freezing precipitation fails to flow from the wing of a jet transport aircraft when subjected to speeds up to rotation speed.

This report documents the preparation activities and the procedures developed for the trials. Because suitable weather conditions did not occur during the window when the test aircraft and crew were available, the tests were not conducted.

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Les rapports de recherche produits au nom de Transports Canada sur les essais réalisés au cours des hivers antérieurs peuvent être obtenus auprès du Centre de développement des transports (CDT). Le programme de la saison hivernale a donné lieu à neuf rapports (dont celui-ci). On trouvera dans la préface l'objet de ces rapports.

16. Résumé

Cette étude avait pour objectif d'établir les conditions où, après perte d'efficacité du fluide antigivrage, les contaminants restent collés sur l'aile d'un avion de transport à réaction amené à des vitesses allant jusqu'à la vitesse de rotation.

Ce rapport rend compte des préparatifs effectués et des procédures établies en vue des essais. Mais ceux-ci n'ont pas eu lieu, faute de conditions météorologiques propices pendant la période où l'équipage et l'avion étaient disponibles.

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EXECUTIVE SUMMARY

At the request of the Transportation Development Centre (TDC) of Transport Canada, APS Aviation has undertaken a research program to further examine the shedding of failed fluids from aircraft wings during takeoff runs up to and including rotation.

Industry regulations dictate that aircraft are restricted from takeoff if ice, frost, snow or slush are adhering to the critical surfaces of an aircraft. Currently, failure of anti-icing fluid is identified visually by observing frozen contamination on the fluid or wing surface. Even if frozen contamination is visible, the observer cannot judge whether this frozen contamination is actually adhering to the wing surface, or not.

1997-98 Winter Season

During the 1997-98 winter season, several trials that involved simulated takeoff runs with a Falcon 20D aircraft were conducted to examine whether failed anti-icing fluid continues to adhere to a wing at lift-off (1). Those trials were intended to fill an information gap thus far unanswered by theoretical analysis and wind tunnel laboratory research.

The 1997-98 series of simulated takeoff run trials provided an initial level of understanding of the question of whether failed anti-icing fluid continues to adhere to a wing at lift-off. These trials proved to be a useful approach toward gaining a more complete understanding of the issue.

The trials provided the first documented evidence related to the nature of the process of shedding of contaminated aircraft anti-icing fluid from aircraft wings during the takeoff run. In some cases, contamination in the form of slush or ice had a film of fluid underneath. This showed freedom of movement and did not adhere to the wing surface, but still remained on the wing after the takeoff run.

1998-99 Winter Season

The 1998-99 winter series of trials included rotation at takeoff speed as part of the simulation, and tested both ethylene and propylene glycol-based SAE Type IV fluids. Nine simulated takeoff runs were executed with a National Research Council Canada (NRC Canada) Falcon 20D research aircraft at Montreal International Airport (Mirabel) (2).

These trials demonstrated that *uncontaminated* ethylene and propylene glycol-based Type IV fluids are almost completely eliminated from the wing surface during the takeoff run by the time the aircraft reaches speeds of 60 to 80 kn.

Trials conducted with ethylene glycol-based SAE Type IV fluid contaminated with artificial freezing rain precipitation demonstrated that ice formations present on the wing, even those with a film of fluid underneath prior to the takeoff run, remained in place following simulated takeoff.

Adhesion or lack of adhesion of ice formations to the wing skin prior to the takeoff run did not influence the shedding of contaminated fluid from the wing. Any fluid that existed outside the ice patches was almost completely eliminated from the wing surface during the takeoff run.

A trial conducted with propylene glycol-based SAE Type IV fluid with a contamination level of 100 percent of the pertinent surface area (complete failure) demonstrated that complete shedding of propylene glycol-based fluid can be expected even at this level of contamination.

A trial involving exposure to precipitation over an extended period was performed. An extreme level of contamination with exposure to precipitation continuing after the fluid had failed over the pertinent section of the wing resulted in the eventual shedding of the underlying fluid layer. Patches of thicker ice developed, some of which were in contact with the wing skin, and this contamination was not eliminated during the simulated takeoff run.

Rotation of the aircraft at normal rotation speed did not appear to cause any further shedding of persistent ice formations.

Following the same duration of exposure to freezing precipitation, the extent of visible contamination may be much greater for propylene glycol-based Type IV fluids than for ethylene glycol-based Type IV fluids. However, the contamination developed on the propylene glycol-based Type IV fluid may be expected to be completely eliminated during the takeoff run, whereas for the apparent lower levels of contamination on the ethylene glycol-based fluids, the visible contamination remained on the wing at simulated takeoff under the test conditions.

1999-2000 Winter Season

The objective of the 1999-2000 winter project was to establish the conditions under which contamination due to anti-icing fluid failure (as a result of accumulated freezing precipitation) fails to be shed from the wing of a jet transport aircraft during simulated takeoff runs up to rotation speed, including

actual aircraft rotation. Overcast skies were specified as a test requirement to avoid heating of wing surfaces due to the sun's radiation.

The purpose of these trials was to provide data for Type IV fluid failures resulting from snow precipitation in temperatures warmer than experienced during testing in the previous season (-25 to -30°C). If time permitted, tests to examine flash-freezing for SAE Type I fluid were also to be conducted.

Another test requirement was production of high quality videotape documentation of the behaviour of the contaminated fluid during the simulated takeoff run.

Suitable weather conditions did not occur during the period that the test aircraft and crew were available, hence the trials were not conducted. Therefore, the intent of this report is to document the experimental program developed for the trials, as well as the detailed planning and scheduling of resources in preparation for the trials. If a decision to proceed with the trials is taken at a later date, this record can serve as the detailed experimental program.

1. REFERENCES

1. Dawson, P., Hanna, M., Chaput, M., *Contaminated aircraft takeoff test 1997/98 winter*, APS Aviation Inc., Montreal, December 1998, Transport Canada report, TP 13316E.

2. Dawson, P., Hanna, M., Ruggi, E., *Contaminated aircraft takeoff test for the 1998-99 winter*, APS Aviation Inc., Montreal, October 1999, Transport Canada report, TP 13479E.

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SOMMAIRE

À la demande du Centre de développement des transports (CDT) de Transports Canada, APS Aviation a entrepris un programme de recherche pour approfondir le comportement, durant la course au décollage jusqu'à la vitesse de rotation et au cabrage de l'avion, des fluides antigivrage déposés sur l'aile d'un avion, une fois qu'ils ont perdu leur efficacité.

Les règlements interdisent tout décollage lorsque de la glace, du givre, de la neige ou une bouillie glacio-neigeuse adhèrent aux surfaces critiques d'un aéronef. À l'heure actuelle, la perte d'efficacité des fluides antigivrage est constatée visuellement, par l'observation de la présence de contamination solide à la surface du fluide. Mais l'observateur n'est pas en mesure de juger si la contamination solide adhère à la surface de l'aile.

Hiver 1997-1998

Pendant l'hiver 1997-1998, plusieurs décollages simulés ont été exécutés avec un avion Falcon 20D. Ces essais visaient à examiner si, après perte d'efficacité du fluide antigivrage, celui-ci reste collé à la voilure au moment du décollage (1). Car les études théoriques et les essais en soufflerie réalisés jusque-là n'avaient pas permis de répondre à cette question.

Or, cette série de décollages simulés a amené les chercheurs à un premier niveau de compréhension de la question de l'adhérence des fluides contaminés lors du décollage. Ces essais ont entre autres permis de valider la démarche expérimentale mise en oeuvre.

En effet, pour la première fois, les chercheurs pouvaient observer directement le processus de décollement du fluide antigivrage contaminé pendant la course au décollage. Ainsi ont-ils constaté que dans certains cas, la contamination, formée de bouillie glacio-neigeuse ou de glace, reposait sur un mince film fluide. Celle-ci n'adhérait donc pas à la surface de l'aile comme telle et pouvait donc, en principe, s'en détacher facilement. Mais tel n'était pas le cas : après le décollage simulé, le fluide contaminé était toujours en place.

Hiver 1998-1999

Pendant la campagne de l'hiver 1998-1999, les essais consistaient non seulement à amener l'avion à la vitesse de rotation mais aussi à le cabrer; les fluides essayés étaient les fluides SAE de type IV à base d'éthylène-glycol et de propylène-glycol. Neuf décollages simulés ont été réalisés avec l'avion de

recherches Falcon 20D du Conseil national de recherches du Canada (CNRC) à l'Aéroport international de Montréal (Mirabel) (2).

Les essais ont révélé que les fluides de type IV à base d'éthylène-glycol et de propylène-glycol *non contaminés* sont presque complètement chassés de la surface de l'aile pendant l'accélération au décollage, alors que l'avion atteint des vitesses de 60 à 80 kt.

Les essais mettant en jeu un fluide SAE de type IV à l'éhylène-glycol contaminé par des précipitations artificielles de pluie verglaçante ont révélé que les accumulations de glace présentes sur l'aile avant le début de la course au décollage, même celles qui reposaient sur un film fluide, étaient toujours en place après le décollage simulé.

Le degré d'adhérence des accumulations de glace au revêtement de l'aile avant la course au décollage n'avait pas d'effet sur l'élimination du fluide contaminé. Hors des plaques de glace, presque tout le fluide antigivre était chassé de la voilure pendant la course au décollage.

Lors d'un essai mettant en jeu un fluide SAE de type IV à base de propylène-glycol contaminé sur 100 p. 100 de la surface étudiée (perte d'efficacité totale) le fluide a été complètement éliminé, malgré le degré extrême de contamination.

Un autre essai a consisté à exposer la voilure à des précipitations pendant une période prolongée. Un degré extrême de contamination a été atteint, car les précipitations se sont poursuivies après la perte d'efficacité du fluide recouvrant la zone étudiée. Le film fluide sous-jacent a ainsi fini par disparaître. Des plaques de glace épaisses se sont alors formées, dont certaines étaient directement en contact avec le revêtement de l'aile. Cette contamination est demeurée en place pendant le décollage simulé.

Le cabrage de l'avion à la vitesse normale de rotation n'a pas semblé contribuer à chasser les accumulations de glace persistantes.

Au bout d'un temps d'exposition semblable aux précipitations givrantes, l'étendue de la contamination visible semble beaucoup plus importante dans le cas des fluides de type IV à base de propylène-glycol que dans le cas des fluides de type IV à base d'éthylène-glycol. Toutefois, il est probable que, dans les conditions d'essai, le fluide de type IV au propylène-glycol contaminé sera complètement chassé de l'aile pendant la course au décollage, contrairement aux fluides à base d'éthylène-glycol qui, ayant atteint des degrés de contamination apparemment moindres, demeureront en place.

Hiver 1999-2000

La campagne d'essais de l'hiver 1999-2000 avait pour objectif d'établir les conditions dans lesquelles la contamination attribuable à la perte d'efficacité des fluides antigivrage (par suite de l'accumulation de précipitations givrantes) refuse de décoller de l'aile d'un avion de transport à réaction au cours de courses au décollage menées jusqu'à la vitesse de rotation, y compris au cabrage de l'avion. Il était impératif que les essais se déroulent sous un ciel couvert, de façon que la chaleur du soleil ne réchauffe pas les surfaces de l'avion.

Ces essais devaient permettre de recueillir des données concernant la perte d'efficacité des fluides de type IV par suite de précipitations de neige à des températures plus élevées que les températures enregistrées au cours des essais de l'hiver précédent (-25 à -30 °C). Pour peu que le temps le permette, des essais devaient aussi être réalisés pour examiner les conditions de congélation instantanée du fluide SAE de type I.

Les essais devaient également permettre de produire un document vidéo de grande qualité sur le comportement de fluides contaminés pendant la course au décollage.

Mais faute de conditions météorologiques propices pendant la période où l'avion de recherches et l'équipage étaient disponibles, les essais n'ont pu avoir lieu. Ce rapport contient donc le programme d'expériences élaboré en vue des essais, de même que la planification et le calendrier d'affectation des ressources. Dans l'éventualité où l'on déciderait de mener ces essais, le présent rapport pourrait servir de programme détaillé.

2. RÉFÉRENCES

1. Dawson, P., Hanna, M., Chaput, M., *Contaminated aircraft takeoff test 1997/98 winter*, APS Aviation Inc., Montreal, December 1998, Transport Canada report, TP 13316E.

2. Dawson, P., Hanna, M., Ruggi, E., *Contaminated aircraft takeoff test for the 1998-99 winter*, APS Aviation Inc., Montreal, October 1999, Transport Canada report, TP 13479E.

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GLOSSARY

APS	APS Aviation Inc.
CDF	Central Deicing Facility
NCAR	National Center for Atmospheric Research
NRC Canada	National Research Council Canada
OAT	Outside Air Temperature
SAE	Society of Automotive Engineers
TDC	Transportation Development Centre

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1. INTRODUCTION

At the request of the Transportation Development Centre (TDC) of Transport Canada, APS Aviation has undertaken a research program to further examine the shedding of failed fluids from aircraft wings during simulated takeoff runs up to, and including, rotation.

1.1 Background

Industry regulations dictate that aircraft are restricted from takeoff if ice, frost, snow or slush are adhering to the critical surfaces of an aircraft. Currently, the failure of anti-icing fluid is identified visually, by observing frozen contamination on the fluid surface. Even if frozen contamination is visible, the observer cannot judge whether this frozen contamination is actually adhering to the wing surface.

1.1.1 1997-98 Winter Season

During the 1997-98 winter season, several trials that involved simulated takeoff runs with a Falcon 20D aircraft were conducted to examine whether failed anti-icing fluid continues to adhere to a wing at lift-off (1). Those trials were intended to fill an information gap thus far unanswered by theoretical analysis and wind tunnel laboratory research.

The 1997-98 series of simulated takeoff run trials provided initial test data pertinent to whether failed anti-icing fluid continues to adhere to a wing at lift-off. These trials provided a useful basis for gaining a more complete understanding of the issue.

In some cases, the contaminated fluid showed freedom of movement and did not adhere to the wing surface, but still remained on the wing after the simulated takeoff run. In general, the contamination was not completely shed from the wing surface during acceleration of the aircraft to rotation speed in the simulated takeoff runs.

The trials underlined the need to conduct further tests at takeoff up to and including rotation to verify the results. As other research had not yet provided answers to the issue, additional simulated takeoff runs were planned for the 1998-99 winter season. A perceived shortcoming of the 1997-98 series of runs was that, although aircraft speed was increased to normal takeoff speed, the aircraft was not rotated at takeoff speed, so the tests did not represent the true takeoff condition.

1.1.2 1998-99 Winter Season

The 1998-99 winter series of trials included rotation at takeoff speed as part of the simulation, and tested both ethylene and propylene glycol-based SAE Type IV fluids. Nine simulated takeoff runs were executed with an NRC Canada Falcon 20D research aircraft at Montreal International Airport (Mirabel) (2).

These trials demonstrated that *uncontaminated* ethylene and propylene glycol-based Type IV fluids are almost completely shed from the wing surface during the takeoff run by the time the aircraft reaches speeds of 60 to 80 kn.

Trials conducted with ethylene glycol-based (EG) SAE Type IV fluid contaminated with artificial freezing rain precipitation demonstrated that ice formations present on the wing prior to the simulated takeoff run persisted following takeoff. This held true regardless of the extent of contamination. In these trials, ice formations covered between 1 percent and 40 percent of the test area on the wing surface.

Adhesion or lack of adhesion of ice formations to the wing skin prior to the simulated takeoff run did not influence the shedding of contaminated fluid from the wing. In these trials, none of the ice formation patches were adhering to the wing prior to the simulated takeoff run. However, on return from the simulated takeoff run, it was noted that many of the ice formations developed some degree of adhecion to the wing skin during the simulated takeoff run.

Any fluid that existed outside the ice patches was almost completely shed from the wing surface during the simulated takeoff run.

A trial conducted on propylene glycol-based (PG) SAE Type IV fluid with a contamination level of 100 percent (complete failure) demonstrated that complete shedding of the propylene glycol-based fluid can be expected in the earlier stages of the contamination process. This result was attributed to the nature of failure of propylene glycol-based fluids. Failures typically occur on the surface of the fluid, which overlies a layer of good, uncontaminated fluid.

A trial involving exposure to precipitation over an extended period was conducted. It produced an extreme level of contamination with exposure to precipitation continuing after the fluid had failed over the pertinent section of the wing. This resulted in eventual elimination of the underlying fluid layer. Patches of thicker ice developed, some of which were in contact

with the wing skin. This contamination was not shed during the takeoff run.

Rotation of the aircraft at normal rotation speed did not appear to cause any further shedding of persistent ice formations.

Samples of uncontaminated fluids were obtained from the aircraft wing subsequent to fluid application. The viscosity values of these samples varied significantly from the measured viscosities of the same fluids received from the manufacturers. Furthermore, the relative viscosities of wing samples of the same fluid brands also varied significantly from one run to another.

Following the same duration of exposure to freezing precipitation, the extent of visible contamination appears to be much greater for propylene glycol-based Type IV fluids than for ethylene glycol-based Type IV fluids. However, the visible contamination developed on the propylene glycol-based Type IV fluid may be expected to be completely shed during the takeoff run, whereas for the apparently lower levels of visible contamination on the ethylene glycol-based fluids, the contamination may be expected to persist on the wing at takeoff. This may have an implication for future *deice/takeoff* decision-making based on end-of-runway scanning of aircraft surfaces using remote ice detection sensor cameras. Information provided by the sensor cameras on the extent of contamination would ideally be evaluated in light of the type of fluid applied. Decisions to return for repeat deicing could depend on the kind of Type IV anti-icing fluid applied.

A principal recommendation of the 1998-99 winter series of trials was that further takeoff run trials be conducted using artificial snow precipitation. The objective of these trials would be to evaluate whether snow provides results similar to freezing rain with respect to visibility, identification, and shedding of contamination from aircraft wings during the takeoff run. These trials would provide the opportunity to obtain detailed documentation of the roughness profile of the contaminated surface for subsequent use in theoretical analyses and wind tunnel research on contaminated surfaces.

A series of trials to be conducted during the 1999-2000 winter season was planned to address this recommendation.

1.2 Work Statement

Appendix A presents an excerpt from the project description in the work statement for the APS Aviation 1999-2000 winter research program.

1.3 Objectives

The objective of this project was to establish the conditions for which contamination due to anti-icing fluid failure, as a result of accumulated freezing precipitation, fails to be shed from the wing of a jet transport aircraft during simulated takeoff runs up to rotation speed, including actual aircraft rotation. Overcast skies to avoid heating of wing surfaces due to the sun's radiation were specified as a test requirement.

The purpose of these trials was to provide data for Type IV fluid failures resulting from snow precipitation for warmer ambient temperatures. If time permitted, tests to examine flash-freezing for SAE Type I fluid were to be conducted.

Another test requirement was the production of high quality videotape documentation of the visible behaviour of the contaminated fluid during the simulated takeoff run.

1.4 Conduct of Trials

Because suitable weather conditions did not occur during the period that the test aircraft and crew were available, the trials were not conducted. The intent of this report is to document the experimental program developed for the trials, as well as the detailed planning and scheduling of resources that took place in preparation for the trials.

2. METHODOLOGY

This section describes the test conditions and the experimental methodology for the 1999-2000 winter series of trials, as well as certain test equipment and personnel requirements.

2.1 Test Site

This series of trials were planned to be conducted at Montreal International Airport (Mirabel). This airport offers an ideal facility for these trials, having long runways with a low level of traffic and a central deicing facility. Figure 2.1 provides a schematic of the airport showing the runways and the location of the Central Deicing Facility.

2.2 Description of Test Procedures

Test dates were selected based on weather forecast and availability of the test aircraft.

The weather condition specified for these tests was dry, with subfreezing outside air temperature. At least one test session was to be conducted at warmer temperatures, near -5°C. Trials at ambient temperatures near -10°C were also planned to study the effect of the different mechanisms of fluid failure at that temperature. Overcast skies were vital to avoid the overheating of aircraft wings from exposure to the sun. Runway conditions were to be clean and dry.

A single area on the port wing just inboard of the fence was selected to serve as the test surface on the Falcon 20D research aircraft (Figure 2.2). The wing test surface area selected is that portion of the wing with a fixed leading edge. A test location inboard on the wing was chosen to reduce the aerodynamic asymmetry between the wings during the rotation phase of the operation. It was planned that NRC Canada staff would mark a reference grid on the forward portion of the wing (Figure 2.3) prior to the test period.

Several modifications were made to procedures from previous seasons:

- In previous trials, pre-defined levels of contamination had been specified. For this season's trials, the extent of contamination was to be determined by:

    1. The point when an experienced observer inside the aircraft cabin first identifies fluid failure; or
    2. Five minutes following that point.

Figure 2.1

Montreal International Airport (Mirabel) Deicing Centre

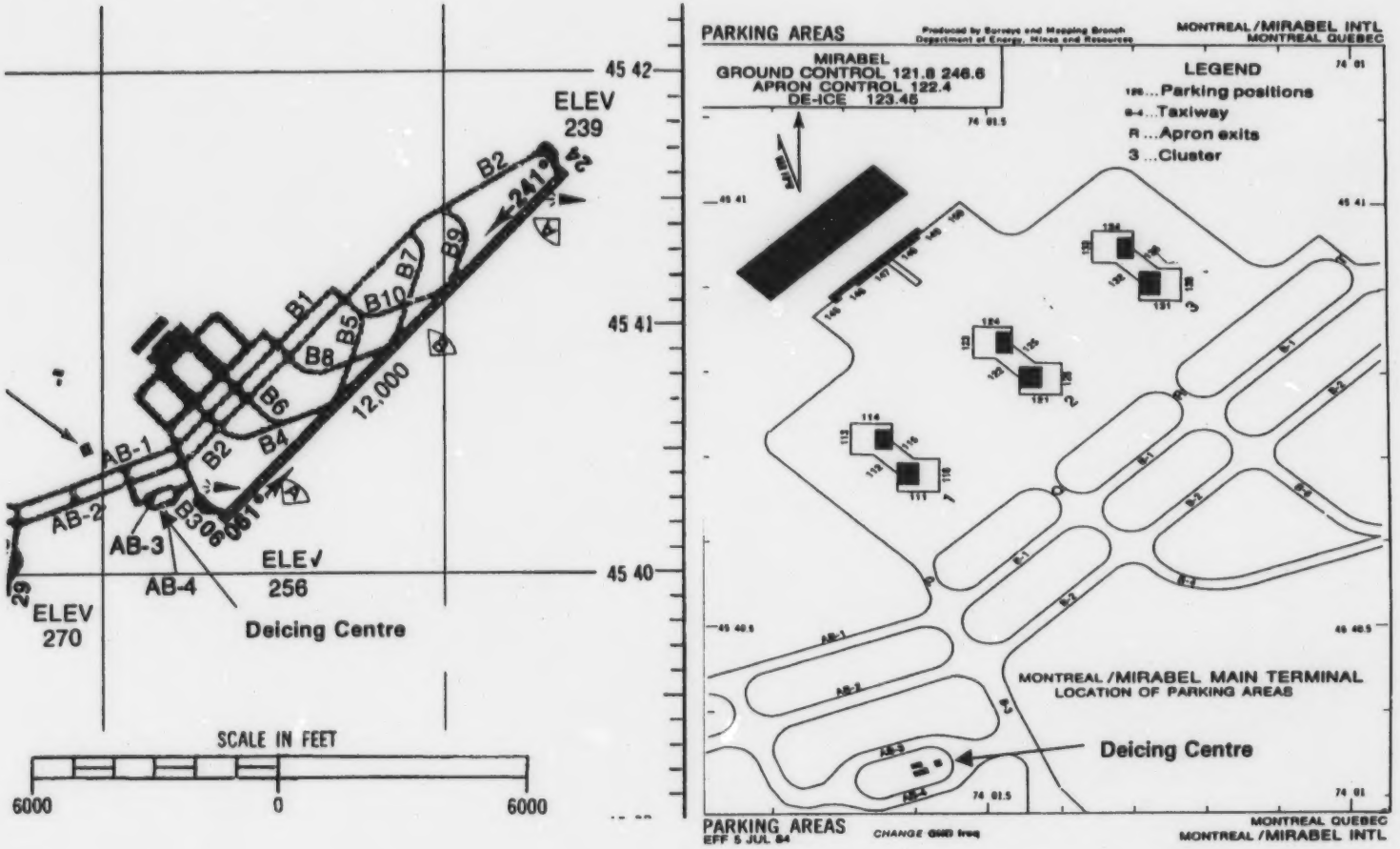

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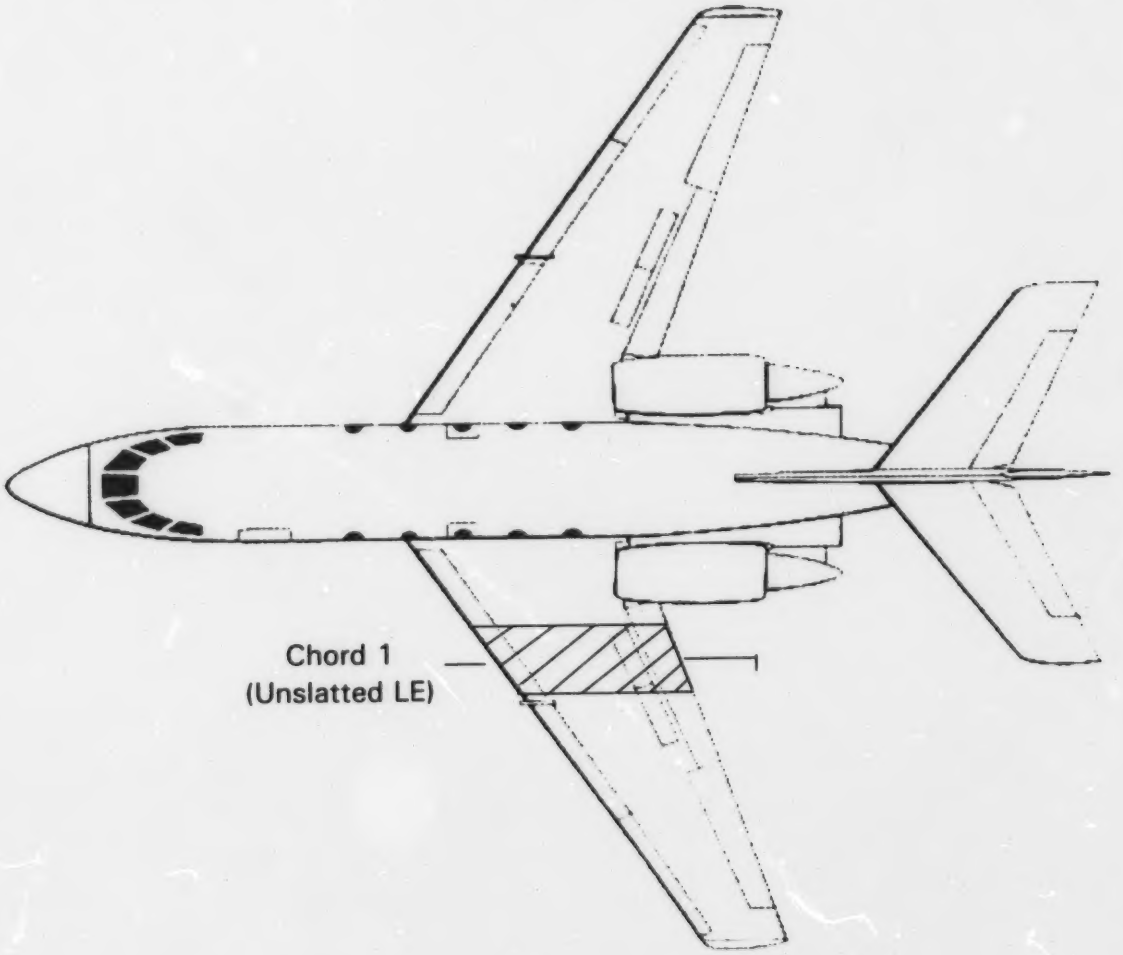
Figure 2.2

Aircraft Test Area Form for Takeoff Run Trials

FALCON 20



Cross-hatched area = Area of wing to be tested

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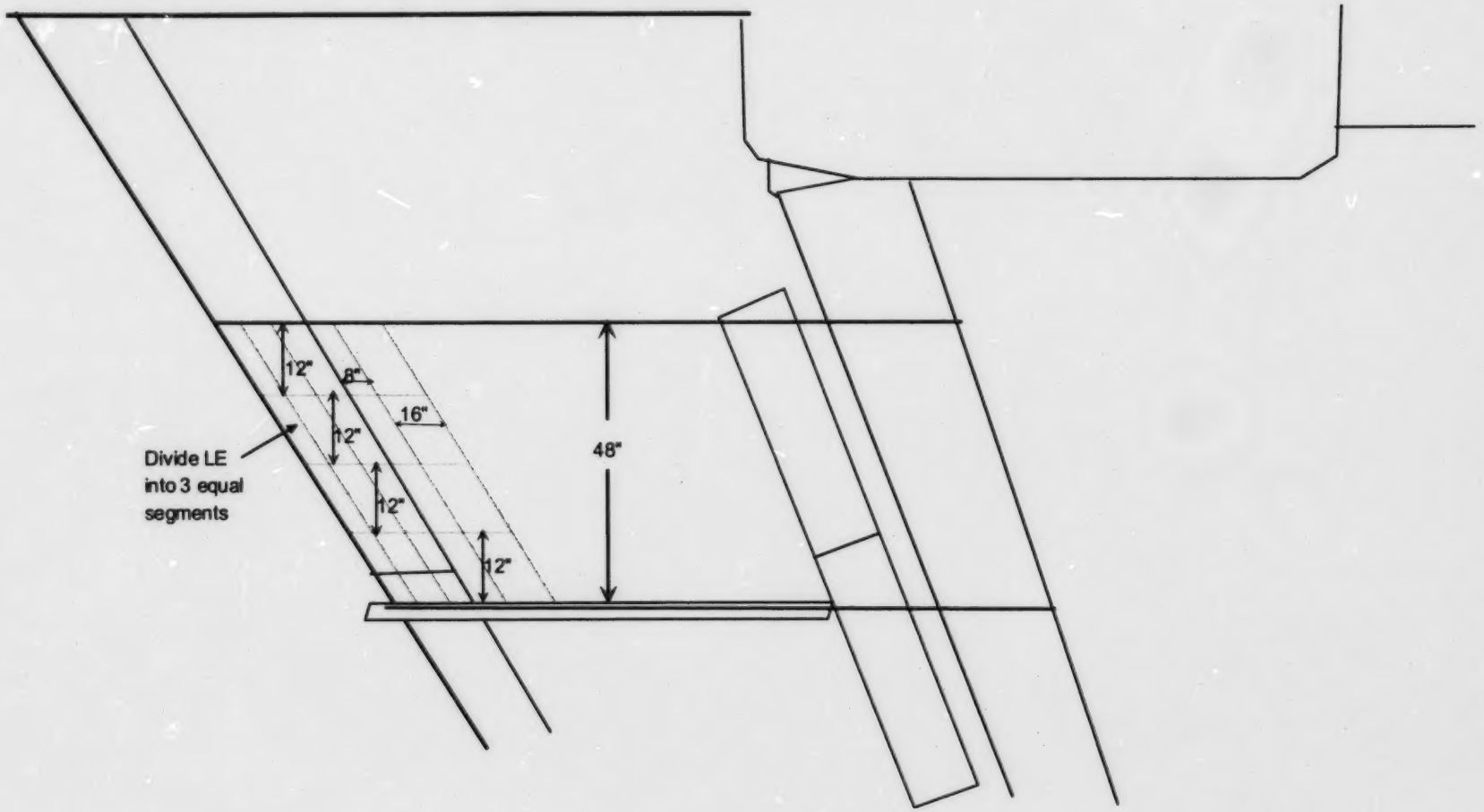
Figure 2.3

Reference Grid for Falcon 20 Wing



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- Freezing rain and snow application equipment were to be calibrated to support delivery near 25 g/dm^2/h. Precipitation was to be measured during the trials by a rate pan mounted on the wing at the edge of the test area.

- Fluid failure time was to be recorded through use of a test plate mounted on the wing.

- Surface roughness of contaminated areas was to be measured by machinist surface finish gauges or documented using photography and reference scales.

- Arrangements were made with Cox and Company Inc. and with BFGoodrich to have staff present with ice detection sensor equipment to assist in documenting contamination levels before and after the takeoff runs.

- Very good quality videotape documentation was specified. Following a review of suitable cameras, it was decided to rent a Sony VX-1000 mini digital video camera for this purpose. In preparation for the trials, NRC Canada staff fabricated a mount within the aircraft for the camera to overlook the wing test area.

Trials to examine the shedding of failed SAE Type IV fluid from aircraft wings during takeoff were assigned top priority. If time permitted after all planned trials on Type IV fluid had been completed, tests using SAE Type I fluid for flash freezing during the takeoff run were to be conducted. Flash freezing trials were to use fluids pre-mixed to specified dilutions. Full strength SAE Type I fluid was to be used for the snow test.

The detailed experimental program, including the test plan for the various trials, is provided in Appendix B.

2.3 Equipment

A list of test equipment is included in Appendix B. Tests involving the freezing rain sprayer and snowmaker require more discussion.

2.3.1 Freezing Rain Sprayer

The freezing rain sprayer used for previous trials was tested to ensure serviceability and to calibrate its rate of delivery. The capability of the sprayer to produce snow was also tested. The calibration procedure follows:

2.3.1.1 Freezing Rain Calibration Procedure

The freezing rain sprayer was calibrated by first establishing a satisfactory spray pattern and replicating sprayer settings established in past tests. Flow from the rain sprayer's two needles was then collected and weighed. The water quantity was then mathematically projected over an area equivalent to the Falcon test area, with an overlap of one foot on all dimensions to account for over-spray.

Wing test area = 4 X 10 = 40 ft^2 = 372 dm^2

With overlap of one ft = 6 X 12 = 72 ft^2 = 668 dm^2

	Run 1	Run 2
Weight of water per 5 minutes (g)	860.8	995.8
Weight per 60 minutes (g)	10330	11952
Flow rate over test area ($g/dm^2/hr$)	28	32
Flow rate over lapped area ($g/dm^2/hr$)	16	18

Conclusion: when this spray is directed over the wing test area, with some overlap at the edges, the rate will be in the order of 25 $g/dm^2/hr$.

2.3.1.2 Snowmaking Trials

Trials to produce snow were unsuccessful.

The design of the freezing rain sprayer was documented in a schematic drawing for future reference. A photo of the plumbing and a schematic are provided in Appendix C.

2.3.2 Snowmaker

The use of commercial snowmaking equipment was investigated in view of the inability of the freezing rain sprayer to generate snow. The alternative of recovering natural snow from the surroundings and spreading it over the wing using a shaker was uncertain, as this activity is dependent on weather conditions and snow accumulation.

Arrangements were made with a local firm, MTN Snow Equipment Inc., for use of a Lenko 950 Snowmaker for these tests. Details on the sprayer and preparation activities for its use are included in Appendix D.

The snowmaker was used during an overnight test session evaluating hot water deicing. OAT was -5°C and wind speed was 8 kph. The effective rate of production of snow was adjusted by varying the distance from the snowmaker to the wing. It was found that tilting the snow gun up in the air and allowing the arc of snow to drift down over the wing improved snow distribution and resulted in a gentler snowfall. The snow gun is shown in operation in Photos 2.1 and 2.2, directing the generated snow toward the test wing. Snowfall rates were about 20 g/dm^2/hr for later tests in the overnight test session, when the process was somewhat refined.

The artificial snow was in the form of a snow pellet with a diameter of about 1.5 mm. The density of the snow was about 0.3 g/cc.

The artificial snow was slightly wet resulting in immediate and strong adherence to the wing skin. The equipment supplier who was present at the tests commented that a colder OAT is necessary in order to achieve a dryer form of snow.

Artificial snow generated by this equipment is suitable for the contaminated aircraft takeoff tests, provided that OAT is colder than -5°C. It is expected that its use will deposit snow over a large part of the test aircraft, and may require deicing of aircraft surfaces other than the designated wing test area.

2.4 Fluids

SAE Type I EG fluid and SAE Type IV EG and PG fluids were to be used.

2.5 Personnel

Eleven APS staff members were to participate in these tests.

Aircraft spraying was planned to be performed by AéroMag 2000.

Correspondence with Aéroports de Montréal (Mirabel) regarding the test is provided in Appendix E.

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Photo 2.1
Lenko 950 Snow Gun

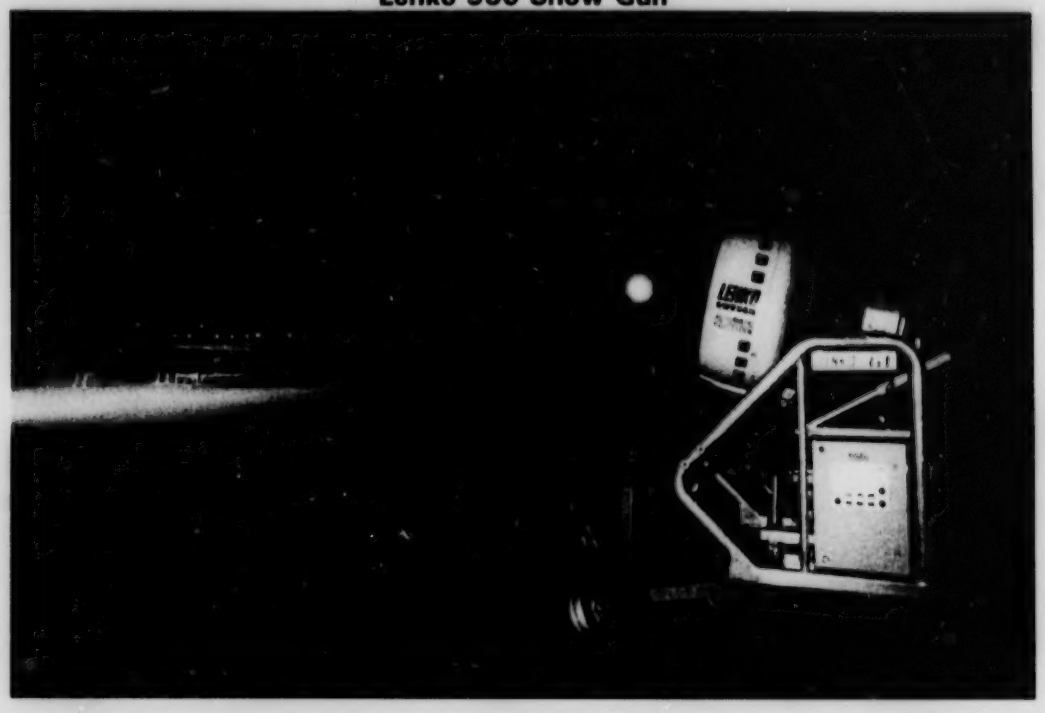
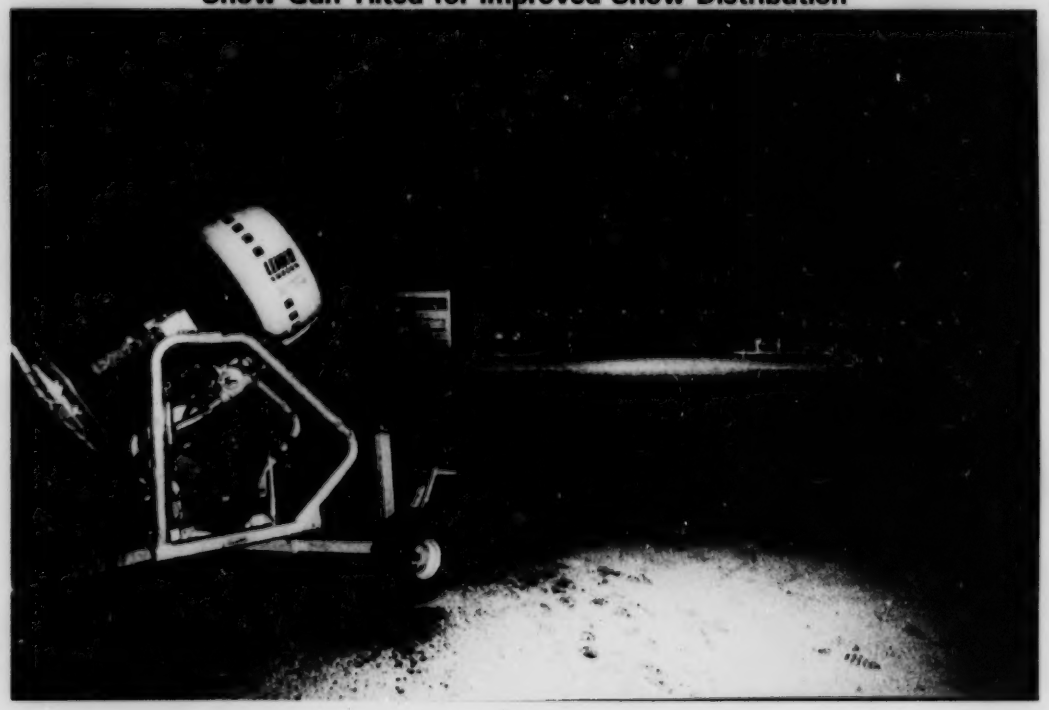


Photo 2.2
Snow Gun Tilted for Improved Snow Distribution



3. RECOMMENDATIONS

It is recommended that:

1. The trials previously approved for the 1999-2000 winter season (as described in Appendix A) be conducted during the 2000-01 winter season.

2. The 2000-01 winter season trials make use of the detailed test procedures and preparation for testing already completed while planning for the previous winter season trials.

3. Those trials be conducted as early as possible during the 2000-01 winter season to take advantage of the extended availability of the snow gun, and to extend the period during which the desired test conditions might occur.

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REFERENCES

1. Dawson, P., Hanna, M., Chaput, M., *Contaminated aircraft takeoff test 1997/98 winter*, APS Aviation Inc., Montreal, December 1998, Transport Canada report, TP 13316E.

2. Dawson, P., Hanna, M., Ruggi, E., *Contaminated aircraft takeoff test for the 1998-99 winter*, APS Aviation Inc., Montreal, October 1999, Transport Canada report, TP 13479E.

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APPENDIX A

TERMS OF REFERENCE – PROJECT DESCRIPTION

PROJECT DESCRIPTION EXCERPT FROM TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT

AIRCRAFT AND FLUID HOLDOVER TIME TESTS FOR WINTER 1999-2000 (December 1999)

5.3 Flow of Contaminated Fluid From Aircraft Wings during Takeoff

Previous trials of simulated takeoff runs provided an improved understanding of the behaviour of contaminated fluid on aircraft wings during this critical phase of the takeoff run. Those trials demonstrated that, with EG-based fluids, any ice formations that existed prior to the takeoff run, remained following the run, regardless of whether the ice had adhered to the wing surface or not. Many ice formations underwent adhesion during the run. With the PG-based fluid, a contamination level of 100 percent was completely eliminated from the wing during the takeoff run.

5.3.1 Purpose of Tests

Evaluate the flow of contaminated fluid from the wing of a Falcon 20 aircraft during simulated takeoff runs.

A test plan will be developed jointly with NRC staff, who operate the aircraft.

Three days of testing at Mirabel airport will be planned.

The objectives of these trials include the production of improved video record of fluid behaviour on the wing during the takeoff run. Particular attention will be given to conducting the trials in appropriate weather conditions. Overcast skies are especially important, to avoid the heating of wing surfaces caused by sun radiation. Ambient air temperatures with range −5° to −10°C are required. Snow precipitation will be used to contaminate the fluids during at least one session.

If deemed necessary, depending on the runway in operation, the aircraft's return taxi will be intercepted to allow the state of fluid on the wing to be examined immediately after the takeoff run.

One or more ice contamination sensors will be used to assist in documenting contamination levels before and after the takeoff runs. A contingency allowance to mount the sensors is included in this proposal. It is assumed that the manufacturers will participate and will provide the sensors for testing.

As part of data gathering, attention will be given to determining the adherence of fluid to the wing.

Data collected during these trials will include:

- Type of fluid applied;
- Record of type and rate of contamination applied;
- Extent of fluid contamination prior to, and following the takeoff run;
- Measurements of thickness, concentration, viscosity, and adherence of clean and contaminated fluid at various stages in the test;
- Observations on fluid appearance and behaviour, photography and videotape records, and ice sensor records; and
- Specifics (speed, aircraft configuration, etc.) during the takeoff runs obtained from NRC Canada personnel.

5.3.2 Conduct of Trials and Assembly of Results

The contractor shall co-ordinate all test activities, initiating tests in conjunction with NRC Canada staff based on forecast weather and aircraft availability. The contractor shall analyze the results and document the findings in a final technical report.

APPENDIX B

EXPERIMENTAL PROGRAM

FIELD TRIALS TO EXAMINE REMOVAL OF CONTAMINATED FLUID FROM AIRCRAFT WINGS DURING THE TAKEOFF RUN

EXPERIMENTAL PROGRAM
FIELD TRIALS TO EXAMINE REMOVAL OF CONTAMINATED FLUID FROM AIRCRAFT WINGS DURING THE TAKEOFF RUN
Winter 1999-2000

Previous trials to examine the elimination of failed SAE Type IV fluid from aircraft wings during takeoff were conducted during the 1997-98 and 1998-99 winter seasons. Those trials, based on simulated takeoff runs using an NRC Falcon 20D aircraft, provided an improved understanding of the subject and showed that the selected test approach was a viable one. Additional trials, during weather conditions not yet tested, will provide a complete cross-section of operating conditions. These additional trials will provide data for fluid failures resulting from snow precipitation, for warmer ambient temperatures, and for SAE Type I fluid.

These trials will be co-ordinated and reported by APS. They will be conducted at Montreal International Airport (Mirabel) (YMX) on a Falcon 20D research aircraft owned and piloted by NRC Canada.

This document provides the detailed procedures and equipment required to support these trials.

1. OBJECTIVES

This project addresses the objective:

- To establish conditions for which contamination due to anti-icing fluid failure in freezing precipitation fails to flow from the wing of a jet transport aircraft up to rotation speed, including actual rotation.

2. TEST REQUIREMENTS

APS will co-ordinate and plan test activities and prepare a final report as well as present results at industry deicing meetings.

APS will provide support for instrumentation, fluid application, and artificial precipitation application. A high-quality digital videotape record of fluid behaviour on aircraft wings during the takeoff run is required. The means to accomplish this will be developed jointly by APS and NRC.

Desired weather conditions are dry, with subfreezing outside air temperature. At least one test session will be conducted at warm temperatures, near –5°C. Trials at ambient temperatures near –10°C are also planned, to study the effect of the different mechanisms of fluid failure at that temperature. Overcast skies are very

different mechanisms of fluid failure at that temperature. Overcast skies are very important to avoid overheating of aircraft wings from exposure to the sun. Runway conditions are to be clean and dry.

For tests involving freezing rain or snow precipitation, the extent of contamination will be determined by:

- The point when an experienced observer inside the aircraft cabin first identifies fluid failure; or
- Five minutes following that point.

Freezing rain and snow equipment will be calibrated to support delivery near 25 g/dm^2/h. Precipitation will be measured during the trials.

Trials to examine the elimination of failed SAE Type IV fluid from aircraft wings during takeoff will be given top priority. Testing of SAE Type I fluid for flash freezing during the takeoff run is a lower priority and will be conducted only if time permits after all useful trials on Type IV fluid have been completed. Flash freezing trials will use fluids premixed to specified dilutions. Full strength SAE Type I fluid will be used for the snow test.

One or more ice detection sensors (if made available by the sensor manufacturers) will be used to assist in documenting contamination levels before and after the takeoff run.

Attachment I provides a description of test procedures. Figure 1 provides an overview plan of the different tests.

3. EQUIPMENT AND FLUIDS

3.1 Equipment

Equipment to be employed is shown in Attachment II.

3.2 Fluids

SAE Type I EG fluid and Type IV EG and PG fluids will be used.

4. PERSONNEL

Eleven APS staff members are required for tests on aircraft at Mirabel airport.

Aircraft spraying will be provided by AéroMag 2000.

An NRC Canada pilot will operate the NRC Canada aircraft.

Attachment III provides task assignments.

5. DATA FORMS

Figure 1	Test Plan
Figure 2	General Form (Every Test)
Figure 2a	General Form (Once per Session)
Figure 3	Wing Test Area for Takeoff Run Trials
Figure 3a	Final Failure Pattern
Figure 3b	Fluid Sampling and Brix Form
Figure 3c	Adherence and Wing Temperature Form
Figure 4	Fluid Thickness on Aircraft

FIGURE 1
TEST PLAN – REMOVAL OF CONTAMINATED FLUID FROM AIRCRAFT WINGS DURING TAKEOFF RUN

TEST #	OAT °C	Fluid	Type of Contamination	Level of Contamination
1	-5	Type IV PG Neat	Snow	1st Failure
2	-5	Type IV PG Neat	Snow	1st Failure plus 5 min.
3	-5	Type IV EG Neat	Snow	1st Failure
4	-5	Type IV EG Neat	Snow	1st Failure plus 5 min.
5	-5	Type IV PG Neat	Freezing Rain	1st Failure
6	-5	Type IV PG Neat	Freezing Rain	1st Failure plus 5 min.
7	-5	Type I EG	Snow	1st Failure
8	-5	Type I EG	Fluid Mixed to FFP = -10°C (OAT - 5°C)	
9	-5	Type I EG	Fluid Mixed to FFP = -8°C (OAT - 3°C)	
10	-10	Type IV PG Neat	Freezing Rain	100%
11	-10	Type IV PG Neat	Snow	1st Failure
12	-10	Type IV PG Neat	Snow	1st Failure plus 5 min.
13	-10	Type IV EG Neat	Snow	1st Failure
14	-10	Type IV EG Neat	Snow	1st Failure plus 5 min.
15	-10	Type I EG	Fluid Mixed to FFP = -15°C (OAT - 5°C)	
16	-10	Type I EG	Fluid Mixed to FFP = -13°C (OAT - 3°C)	

FIGURE 2

GENERAL FORM (EVERY TEST)

(TO BE FILLED IN BY WING OBSERVER)

DATE: _____ **AIRCRAFT TYPE:** FALCON 20

RUN #: _____ **WING:** PORT

DIRECTION OF AIRCRAFT: _____ DEGREES **DRAW DIRECTION OF WIND WRT WING:**

DEPARTURE TIME FROM DE-ICING BAY: _____

TIME WING EXAMINED AFTER TAKEOFF RUN: _____

1st FLUID APPLICATION			
Actual Start Time:	_____ am / pm	**Actual End Time:**	_____ am / pm
Amount of Fluid Sprayed:	_____ L / gal	**Type of Fluid:**	_____
Fluid Sample Collected from Truck or Barrel:	Y / N		
2nd FLUID APPLICATION			
Actual Start Time:	_____ am / pm	**Actual End Time:**	_____ am / pm
Amount of Fluid Sprayed:	_____ L / gal	**Type of Fluid:**	_____
Fluid Sample Collected from Truck or Barrel:	Y / N		
CONTAMINANT SPRAY APPLICATION			
Actual Start Time:	_____ am / pm	**Actual End Time:**	_____ am / pm

End of Test Time: _____ (hr:min:ss) am/pm

COMMENTS: _____

MEASUREMENTS BY: _____

HANDWRITTEN BY: _____

File: h:\cm1589\procedures\falcon 20\Data Forms.XLS
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Version 2.0

FIGURE 2a

GENERAL FORM (ONCE PER SESSION)

(TO BE FILLED IN BY OVERALL COORDINATOR)

AIRPORT: YMX

AIRCRAFT TYPE: FALCON 20

EXACT PAD LOCATION OF TEST: _____

AIRLINE: _____

DATE: _____

FIN #: _____

APPROX. AIR TEMPERATURE: _____ °C

FUEL LOAD: _____ LB / KG

TYPE I FLUID APPLICATION	*TYPE IV FLUID APPLICATION*
TYPE I FLUID TEMP: _____ °C	**TYPE IV FLUID TEMP:** _____ °C
Type I Truck #: _____	**Type IV Truck #:** _____
Type I Fluid Nozzle Type: _____	**Type IV Fluid Nozzle Type:** _____

COMMENTS: _____

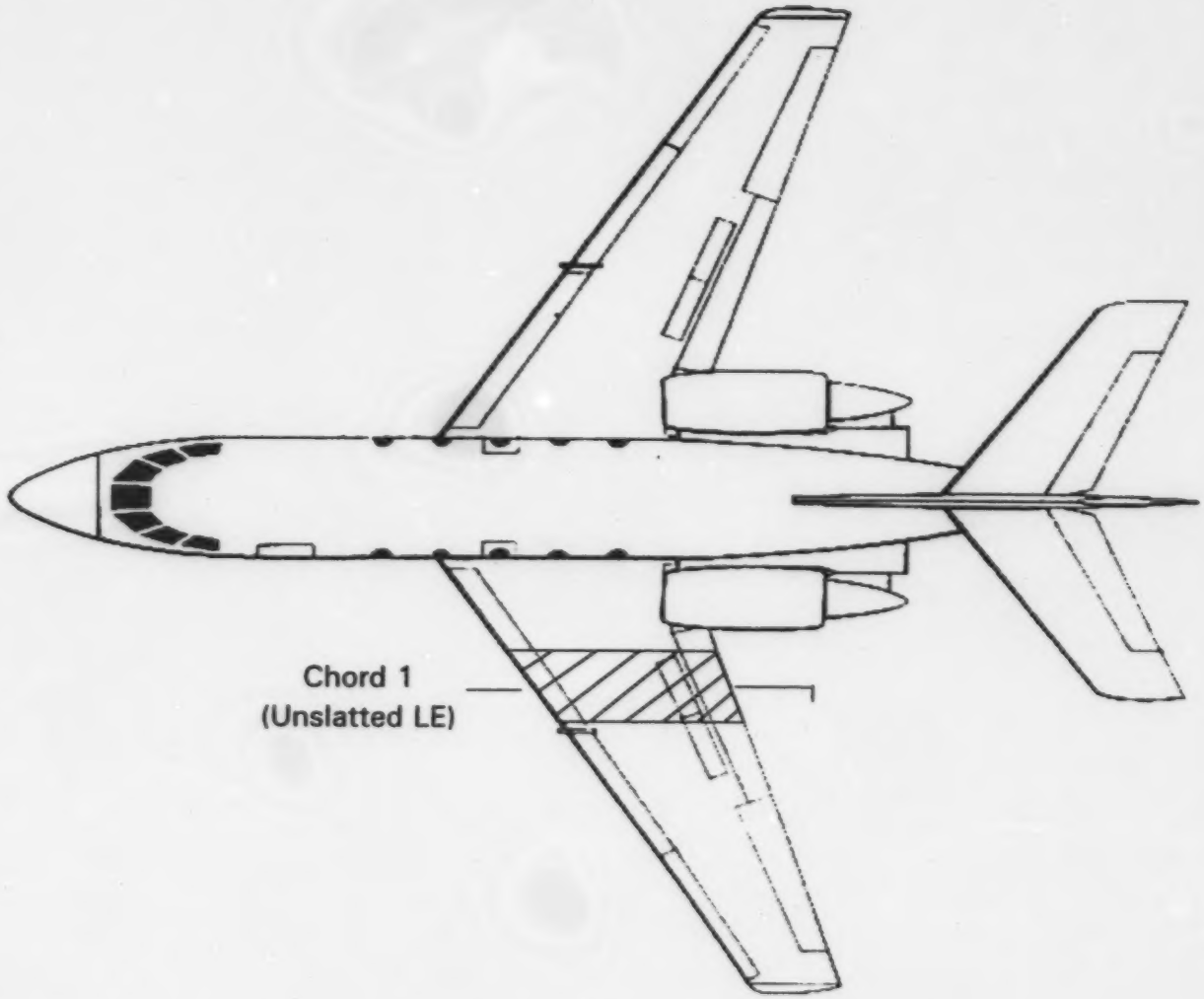
MEASUREMENTS BY: _____

HANDWRITTEN BY: _____

FIGURE 3

WING TEST AREA FOR TAKEOFF RUN TRIALS

FALCON 20



Cross-hatched area = Area of wing to be tested

FIGURE 3a

FLUID FAILURE PATTERN FORM

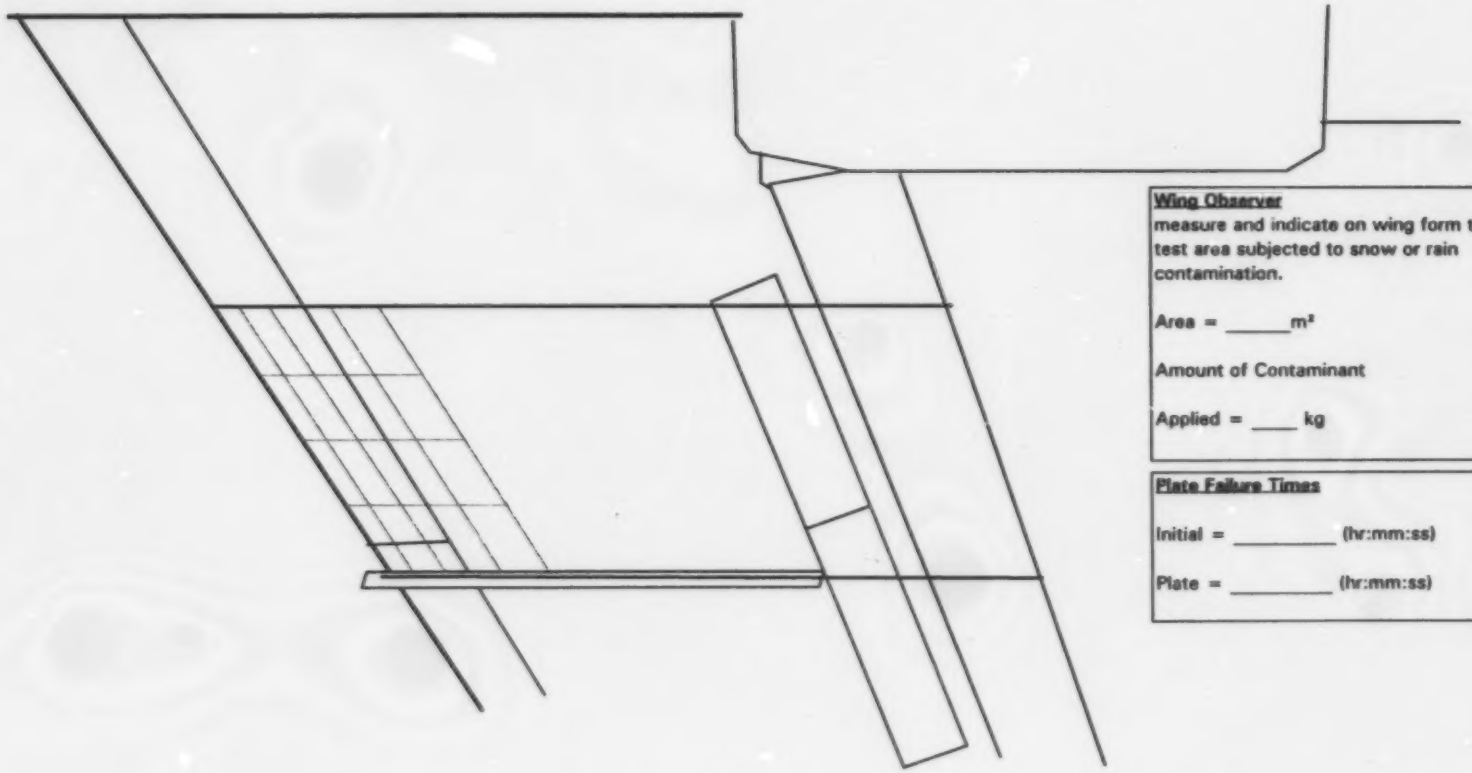
FALCON 20

Date: _____ Time: _____ Run Number _____

Failure Contours: Before Takeoff _____ Location of Observer: Cabin _____ Fluid Type: _____

After Takeoff _____ Wing _____

DRAW FAILURE CONTOURS ACCORDING TO THE PROCEDURE



Wing Observer

measure and indicate on wing form the test area subjected to snow or rain contamination.

Area = _____ m^2

Amount of Contaminant

Applied = ____ kg

Plate Failure Times

Initial = _____ (hr:mm:ss)

Plate = _____ (hr:mm:ss)

COMMENTS: _____

_____

_____

_____

OBSERVER: _____

ASSISTED BY: _____

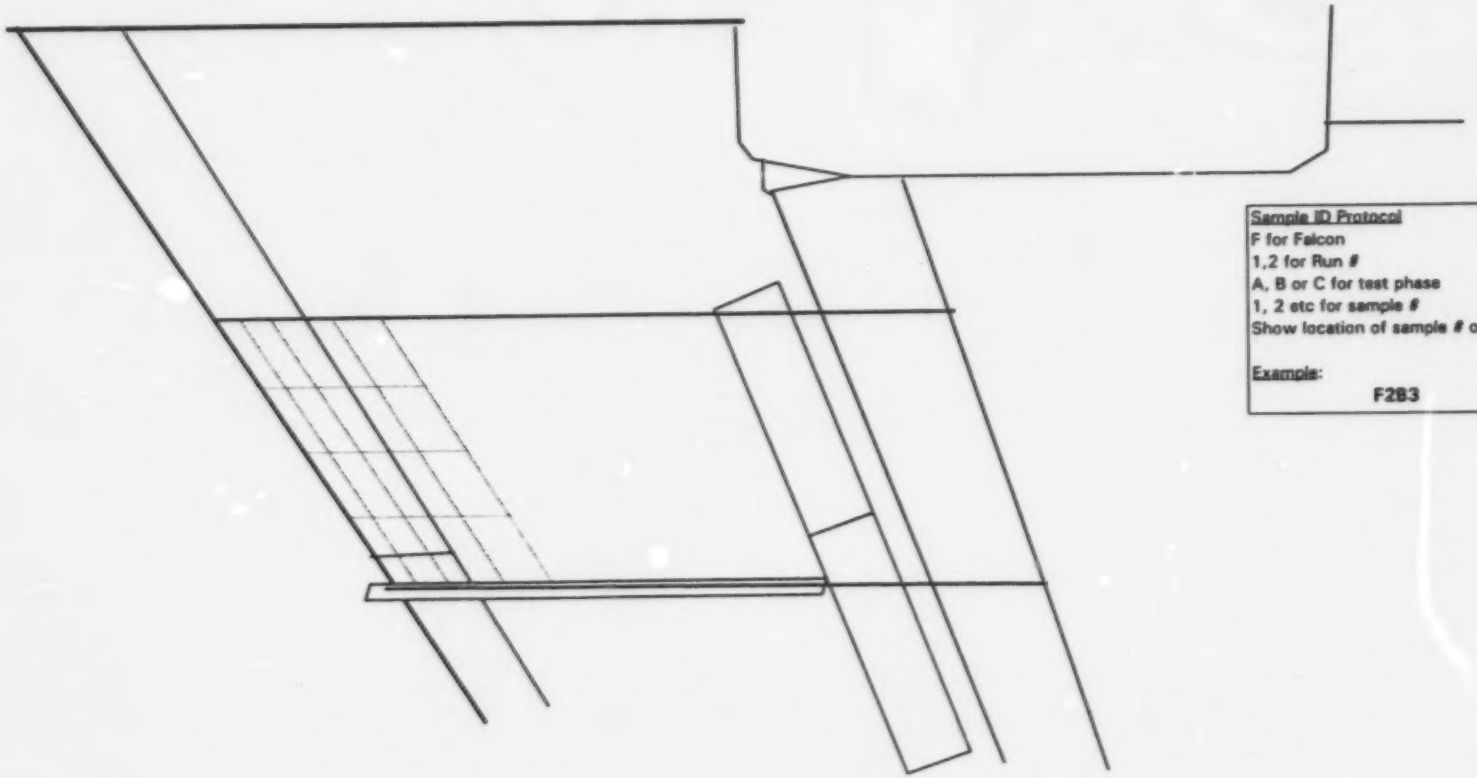
FIGURE 3b

FLUID SAMPLING AND BRIX FORM

FALCON 20

Date: _____ Time: _____ Run Number _____

Test Phase: A- before contamination ☐ B- before takeoff ☐ C- after takeoff ☐



Sample ID Protocol
F for Falcon
1,2 for Run #
A, B or C for test phase
1, 2 etc for sample #
Show location of sample # on wing form.

Example:
F2B3

COMMENTS: _____

OBSERVER: _____

ASSISTED BY: _____

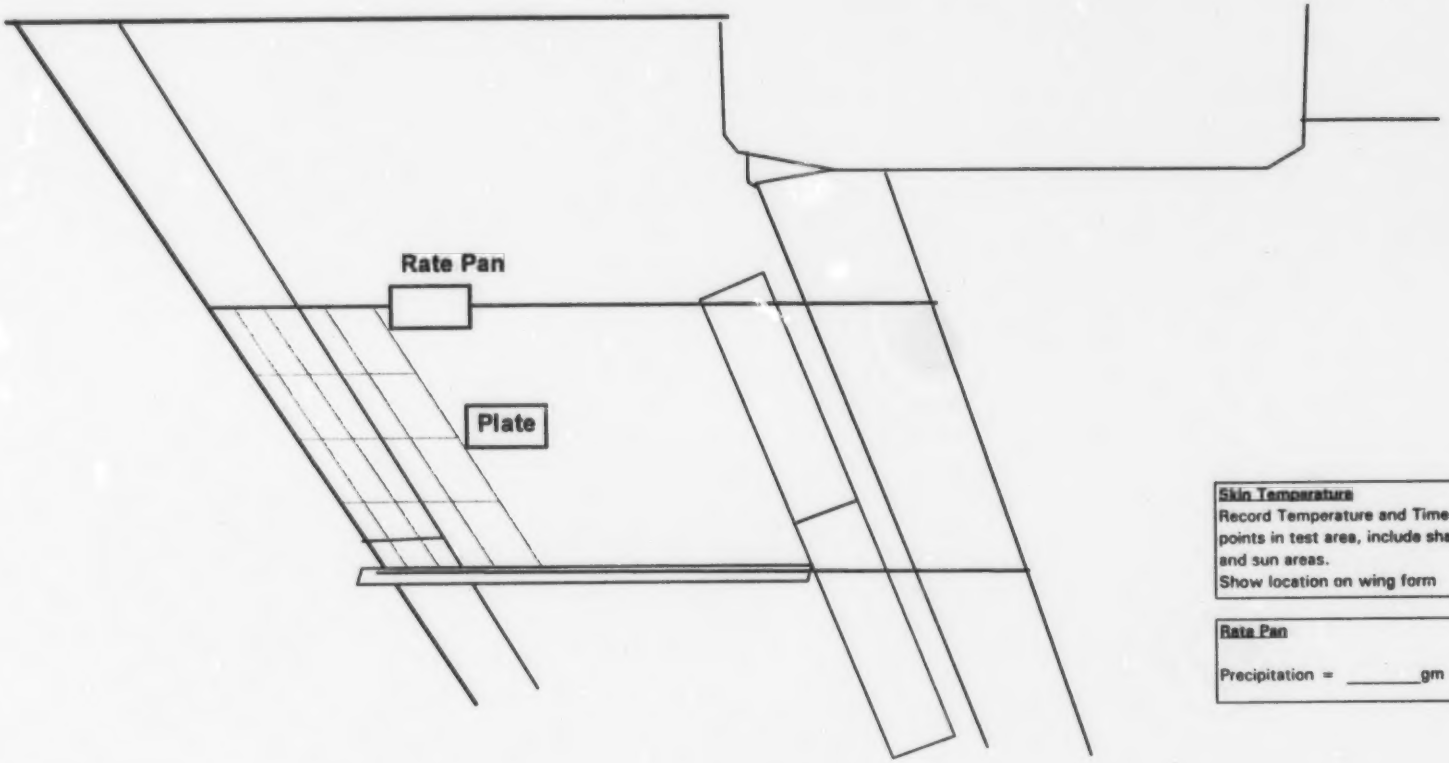
FIGURE 3c

ADHERENCE AND WING TEMPERATURE FORM

FALCON 20

Date: _____ Time: _____ Run Number _____

Test Phase: A- before contamination ☐ B- before taxi ☐ C- after takeoff ☐



Skin Temperature
Record Temperature and Time at several points in test area, include shaded and sun areas.
Show location on wing form

Rate Pan
Precipitation = _____gm

During Takeoff Run:

OAT = _____ °C

Wind = _____ kph

RH = _____ %

Sky Condition: _____

OBSERVER: _____

ASSISTED BY: _____

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FIGURE 4

FLUID THICKNESS ON AIRCRAFT

AIRPORT: YMX

AIRCRAFT TYPE: FALCON 20

DATE:

WING: PORT (A)

DRAW DIRECTION OF WIND WRT WING:

RUN #:

DIRECTION OF AIRCRAFT: DEGREES

	Before Rain Spray		Before Takeoff		After Takeoff	
Location	Time	Gauge	Time	Gauge	Time	Gauge
1						
2						
3						
4						
5						
6						
7						
8						
9						

Location

1 - LE Nose

2,8- Half-way

3,4,6,7 - 1" from joint

5 - As far as can reach

9 - 6" from TE

Note:

Give priority to circled locations; measure other locations only if time allows.

COMMENTS:

MEASUREMENTS BY:

HAND WRITTEN BY:

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ATTACHMENT I
TEST PROCEDURES

1. PRE-TEST SETUP

- Co-ordinate with AéroMag for deicing spraying and access to deicing pad.
- Co-ordinate with Aéroports de Montréal (Mirabel) and Nav Canada and secure an agreement to inspect the aircraft on the taxiway soon after it turns off the runway.
- Co-ordinate with BFGoodrich and/or Spar/Cox for availability of ice detection sensors. Arrange for vehicle with mast, to mount camera(s).
- Arrange for security escorts and passes. A number of visiting observers may be present and will require security passes and escorts.
- Arrange with NRC Canada to use high quality digital video camera to videotape behaviour of fluid on the wing when the aircraft is taxiing and during the takeoff run.
- Arrange with NRC Canada to apply grid markings to test area on wing.
- Arrange delivery of Type IV PG fluid (neat) to Central Deicing Facility at YMX.
- Prepare freezing rain sprayer. Calibrate rate of delivery. Target rate is 25g/dm^2/h.
- Prepare for snow application. Attempt to produce snow from existing rain sprayer through modification. Calibrate rate of delivery. Target rate is 25g/dm^2/h.
- Provide alternative approach using snow spreader with natural snow from the environment. Calibrate rate of delivery. Target rate is 25g/dm^2/h.
- Prepare Type IV fluid sprayer unit.
- Prepare Type I fluid sprayer unit (hot water heater/sprayer built for hot water trials)with larger hose and nozzle for faster discharge.
- Transport equipment to Mirabel.

2. CONDUCT CONTAMINATION TESTS

- Brief team including AéroMag 2000.
- Synchronise times on all test instruments and watches.
- Mark wing for tests, indicating the boundaries of the test area and reference grid markings. Measure the area to be subjected to rain and to snow contamination.
- Mount test plate and rate pan on wing surface at position indicated on figure.
- Install and test digital camera at overwing exit position.
- Ensure all other cameras and instruments are ready for tests.

For Type IV fluids tests:

- Spray the designated wing area following standard procedures for two-step fluid application.
- Measure fluid thickness at several points.

- Collect Type IV fluid samples for viscosity tests prior to and following precipitation.
- Apply the freezing rain or snow over the test area. Measure the amount of contaminant applied.
- Record fluid failure times (initial and plate) on the test plate mounted on the wing surface.
- When the desired level of contamination on the wing has been reached, stop the application. Identify and record the wing area contaminated and the degree of contamination on the data sheet. Also record the ice detection sensor readings. Measure thickness, adherence and dilution of fluid at points of contamination and at several locations along the chord. Photograph surface roughness using scale for reference. Measure wing skin temperature on leading edge and main wing; note temperature and locations measured on wing form.
- Observe failures from the aircraft cabin.
- Photograph and videotape appearance and pattern of failure.

For Type I fluid snow tests:

- Spray the designated wing area following standard procedures for one-step fluid application.
- Apply the snow over the test area. Measure the amount of contaminant applied. Measure the area of the wing subjected to snow contamination.
- When the desired level of contamination has been reached, stop the application. Identify and record the wing area contaminated and the degree of contamination on the data sheet. Also record the ice detection sensor readings. Measure thickness, adherence and dilution of fluid at points of contamination and at several locations along the chord. Measure wing skin temperature on leading edge and main wing; note temperature and locations measured on wing form.
- Observe failures from the aircraft cabin.
- Photograph and videotape appearance and pattern of failure.

For Type I fluid flash freezing tests:

- First clean any contamination from the wing with spray from the deicing vehicle. Squeegee as much fluid from the wing as possible. Apply the Type I test fluid using the heater/sprayer built for hot water trials, ensuring that any remnants of the previous fluid are removed.
- Measure thickness and strength of fluid at several locations along the chord. Measure wing skin temperature on leading edge and main wing; note temperature and locations measured on wing form.

Takeoff run:

- Remove test plate and rate pan from wing surface.
- With test crew onboard, perform the takeoff run to rotation speed. Videotape (with the installed digital video camera) the behaviour of the fluid on the wing during the takeoff run, capturing any movement of fluid or of contamination.
- With a second video camera, record readings from the air speed indicator.
- During the takeoff run, record OAT, wind, RH and sky condition.
- Examine the wing as soon as possible after the takeoff run. This may take place when the aircraft has turned off the runway and halted on the taxiway, or at the deicing facility if the takeoff run ends nearby. Document fluid

condition. Give attention to any frozen patches to determine whether they have grown during the run. Measure thickness, adherence and Brix of any fluid remaining, as well as temperature of wing skin at locations measured before the takeoff run. Photograph any remnants of fluid still on the wing and, if possible, scan the area with the ice detection sensor. Photograph surface roughness using scale for reference. Lift Type IV fluid samples for later viscosity measurement.

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ATTACHMENT II
ADHERENCE OF CONTAMINATED FLUID
TEST EQUIPMENT CHECKLIST

TASK
Logistics for Every Test
Monitor forecast
Coordinate with NRC, TDC
Call personnel
Rent panel truck / Rent pickup / Rent generator for Type IV sprayer/ 2 other generators
Rent personnel van for APS team to/from APS site and YMX
Rent mast truck for Cox sensor mounting
Rent cube van for Cox sensor setup
Rent generator to support aircraft heating.
Advise Aéromag; arrange for deicing truck with Types I and IV
Advise YMX airport operations
Advise Cox, BFGoodrich
Advise sensor truck operator
Advise security agency, confirm number of passes and escorts
TEST EQUIPMENT
Producing Contamination
Freezing rain sprayer
Water for rain sprayer
Sprayer fittings for making snow
Snow shaker & snow
Tubs for snow
APS generator
Scales to weigh amount of rain or snow applied
Spraying Fluid
Type IV sprayer with supporting equipment/ generator
PG Type IV – Neat
Type I heater/sprayer
Type I fluid mixed to correct FFP
Fluid sample containers
Brixometer
Crane for lifting fluid barrels
Large wing squeegees
Sensor Support
Spar/Cox camera & support, plus TV and VCR with videotape
BFGoodrich sensor camera
Generator(s) to support sensor
Table and 3 chairs for Cox setup in cube van
Dish heater for cube van
Lights for cube van
12 V battery charged for BFGoodrich camera
Tall rolling stair for BFG camera operator
Aircraft Support
Generator to support aircraft heating

220 V extension cable for Falcon heater with correct plug
Wing marker to delineate test area boundary and mark points for test; plus solvent and wipers
Pylons
Aluminum test plate and rate pan on legs, to mount on wing
Camera Equipment
Digital video camera for a/c overwing exit
Video camera X 2
Blank videotape
Support equipment for video camera
Still camera and film
Digital still camera
Super 8 film
Metric scale for photographing surface roughness
Microscope
Laptop PC
Forensic scales
General Support Equipment
Fuel for generators
Large tape measure
Step ladders – short + tall
Electrical extension cables
Radios X 4
Fire extinguisher
First aid kit
Test Equipment
Test procedures
Data forms
Clipboards
Pencils
Pencil sharpener
Wing markers for sample locations and solvent
Tape measures; long survey tape plus standard carpenters tapes
Thickness gauges
Adherence instrument and spare batteries
Thermometer for OAT
Thermometer probe and spare batteries
Brixometer X 3
Devices for lifting fluid samples for Brix tests
Devices to lift fluid samples for viscosity
Sample bottles for viscosity measurement
Vaisala RH meter
Wind gauge
Personnel Equipment
Hearing protectors
Coffee pot/ coffee/ milk and sugar/ cups/ donuts
Water for drinking and for making coffee
Binoculars
Security passes

ATTACHMENT III
APS STAFF TASK DESCRIPTION
AIRCRAFT TRIALS AT MIRABEL AIRPORT

Co-ordinator

- Initiate test with NRC Canada, TDC, Aéromag.
- Advise all other agencies, including security authorities and sensor manufacturers.
- Advise APS test team.
- Ensure that all required equipment is available and functional.
- Provide direction as required during the tests.
- Ensure all data are collected and recorded, and all test records submitted.

Video

- Video tape test set-up, outside and onboard the aircraft.
- Videotape fluid on wings "before and after" each run, ensuring that constant viewing angles are used to facilitate comparisons.
- With aircraft crew, install digital camera on-board at the temporary emergency exit and ensure proper operation.

Photographer

- Photograph test set-up.
- Photograph "before and after" views of failed fluid on wing, ensuring that constant viewing angles are maintained to enable comparisons.
- Photograph contaminated fluid roughness detail using a scale for reference.
- Record images of roughness using microscope/laptop combination with forensic scale.

Ice Detection Sensor Operator

- Provide support for the operation of the two ice detection systems.
- Operate the Cox ice detection sensor during the spray and contamination phase, and following the takeoff run, in the absence of Cox representatives.
- Document each sensor camera positioning relative to the wing test area, for each test run.
- Download data from the sensor system databases.

Wing Observer

- Maintain General Form for every test (Figure 2).
- Record pattern of contamination on Form 3a. Give attention to detail of any frozen patches, for comparison with after-run size and appearance.
- Record area subjected to contamination and amount of contamination (get from spray team).
- Record fluid failure time on test plate mounted on wing.
- Examine and record fluid or contamination remaining after the takeoff run. Give attention to detail of any frozen patches, for comparison.

Fluid Thickness, Brix and Fluid Samples

- Collect samples of Type IV fluid for subsequent viscosity tests
- Record specifics for each sample.

Sampling Protocol

a) Before Contamination

Take 2 samples adjacent to test area; note locations on sampling form (Figure 3b).

b) Before Takeoff Run

Take samples as directed by PD or JD; note locations on form.

c) After Takeoff Run

Sample any fluid remaining, including failed area. Note locations on sampling form.

- Measure thickness and Brix of fluid on wing at points of contamination and other selected chordwise locations. Record on aircraft form (Figure 3a).

Adherence, Wing Temperature, OAT/Wind/RH/Sky Condition

- Measure adherence of fluid on wing at points of contamination and other selected chordwise locations. Record on aircraft form (Figure 3c).
- Measure temperature of wing surface before and after takeoff run. Record temperature and indicate points measured on Figure 3c. Note condition of sky.
- Record OAT, RH and wind during each takeoff run.
- Install test plate and rate pan on wing prior to each test.
- Weigh and record the amount of precipitation collected during the test in the rate pan mounted on the wing.
- Remove test plate and rate pan from wing following each test, prior to starting the engines.
- Install test plate and rate pan prior to each test.

Freezing Rain and Snow Operator and Assistant

- Ensure proper functioning of rain/snow sprayer equipment, giving attention to preventing lines from freezing between tests.
- Spray freezing rain/snow over the wing test area until advised that desired level of contamination has occurred.
- Operate Type IV fluid sprayer.
- Weigh amount of water or snow applied as contaminant during test; report amount to wing observer.

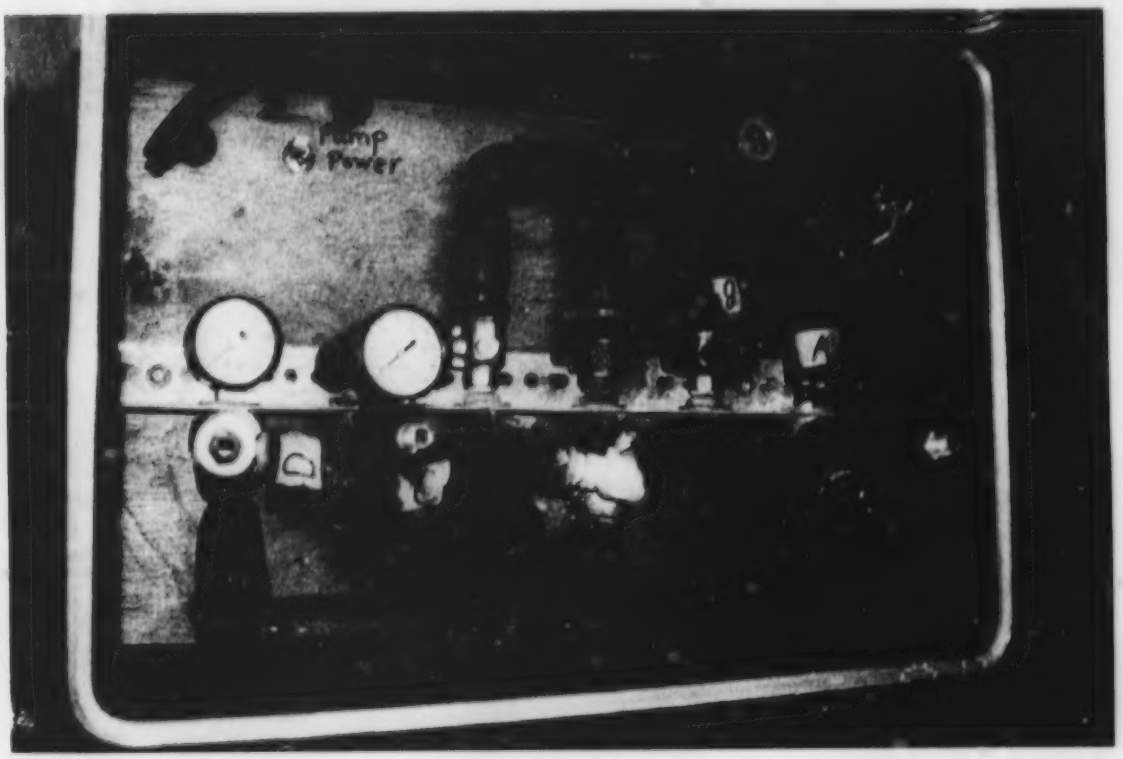
Cabin Observer

- Make observations of failures on wing from inside the cabin.
- When first failure is observed, communicate advice to stop contamination.
- Enlist and instruct Falcon 20 pilot to record pilot observations.
- Occupy jump seat during aircraft runs to videotape air speed instrument.

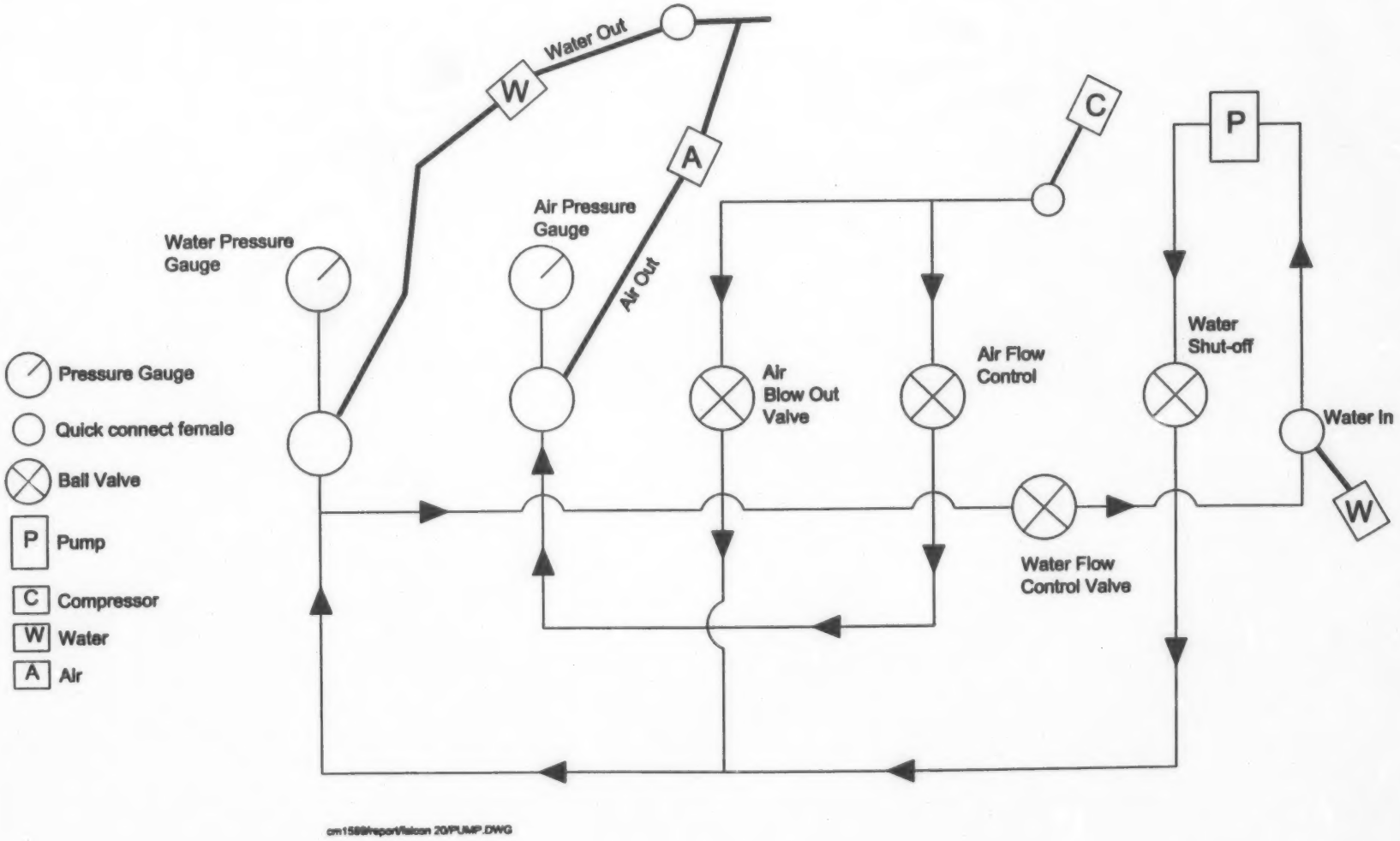
APPENDIX C

FREEZING RAIN SPRAYER

Freezing Rain Sprayer Plumbing



Freezing Rain Sprayer Schematic



APPENDIX D

LENKO 950 SNOW GUN

APPENDIX D

LENKO 950 SNOW GUN

RENTAL ARRANGEMENT

The unit was contracted for a one week duration, but as it was late in the season, the supplier agreed that it could be kept at the airport and used whenever conditions were suitable. MTN Snow Equipment Inc. agreed to have a technician present when the unit was used, and to relocate the unit at Mirabel Airport when needed.

Charles Stenger 514 421-6324
www.mtnequipment.com

At the end of the season, because the unit had been used only once, the supplier agreed to extend the agreement into the early part of the 2000-01 winter season.

SETUP

The snow gun requires a 600 V power supply, 40 A peak, 23 A running. For the hot water tests, a 600 V generator was rented from Hewitt.

The snow gun is equipped with a 5 cm (2") male Kamlock fitting for water supply. MTN Snow Equipment lent APS an adaptor (5 cm (2") female Kamlock and 5 cm (2") female NPT). To enable use with the fire hydrant at the Dorval Airport Fire Station, we purchased another adaptor (5 cm (2") male NPT and 6 cm (2½") male QST).

Captain Cloutier at the fire station (514-633-3301) gave permission to use the fire hydrant, and also offered to lend any hose lengths that were necessary to reach the test site. For tests using this water source, Pad 5 at the Central Deicing Facility (CDF) is the closest. Note that use of this pad requires that taxi-way Juliet (in front of the fire station) be closed.

For use of the snow gun at the Mirabel CDF, an alternative water supply is needed as the site is not serviced by the water system. AéroMag 2000 offered to make available its 19 000 L (5000 gallon) water tanker. They will fill it when advised by APS and locate the tanker at the test site. It is desirable to have the water supply as cold as possible, so the filled tanker

must be kept outside. The tank can't be filled the night before tests because of the risk of freezing. MTN Snow Equipment advises that with a tank water temperature of 10°C, an OAT of at least -6°C would be necessary for snowmaking. An AéroMag mechanic reported that the tanker water outlet has a quick disconnect camlock, and confirmed that AéroMag has a range of fitting adaptors on hand.

The snow gun can be fitted with up to 5 water rings, each with 90 spray nozzles. Each ring pulls 114 L (30 gallons) of water per minute. For APS tests, the snow gun is equipped with 2 water rings.

APPENDIX E

CORRESPONDENCE WITH AÉROPORTS DE MONTRÉAL

(MIRABEL)

FACSIMILE/TÉLÉCOPIE

TO/DESTINATAIRE :	Robert Lussier
COMPANY/COMPAGNIE :	ADM Mirabel
TEL No TÉL. :	450 476-5359
FAX No TÉLÉCOPIEUR :	450 476-3178

FROM/EXPÉDITEUR :	Peter Dawson **FILE No DE DOSSIER :** cm1589	
TEL No TÉL. :	**(514) 878-4388**	**1100 René-Lévesque Blvd. West** **Suite 1340** **Montréal, Québec**
FAX No TÉLÉCOPIEUR :	**(514) 861-6310**	**H3B 4N4**
DATE :	2000-06-13	**COVER PAGE +/** **PAGES À SUIVRE :** 0

ADDITIONAL NOTES ADDITIONNELLES :

Bob

The tests on behalf of Transport Canada on the NRC Falcon20 conducted during the past 2 winter seasons at Mirabel airport are planned to be repeated this year. These tests examine the flow of contaminated anti-icing fluid from the aircraft wing during a simulated takeoff run. As previously, we will arrange for security escorts with sufficient passes. Preparing the wing for testing will be conducted at the deicing center, and Aéromag 2000 are aware. This year, we may want to meet the returning aircraft on the taxiway to examine the condition of the fluid on the wing as soon as possible following the takeoff run. We will have our security escort in contact with the tower for this operation.

The planned time for testing is during the period from Mar 06 to17. We will be looking for temperatures of -5 to -10°C, dry runways and overcast skies.

Best regards, Peter